REGIONAL BREWER CALIBRATION CENTER-EUROPE

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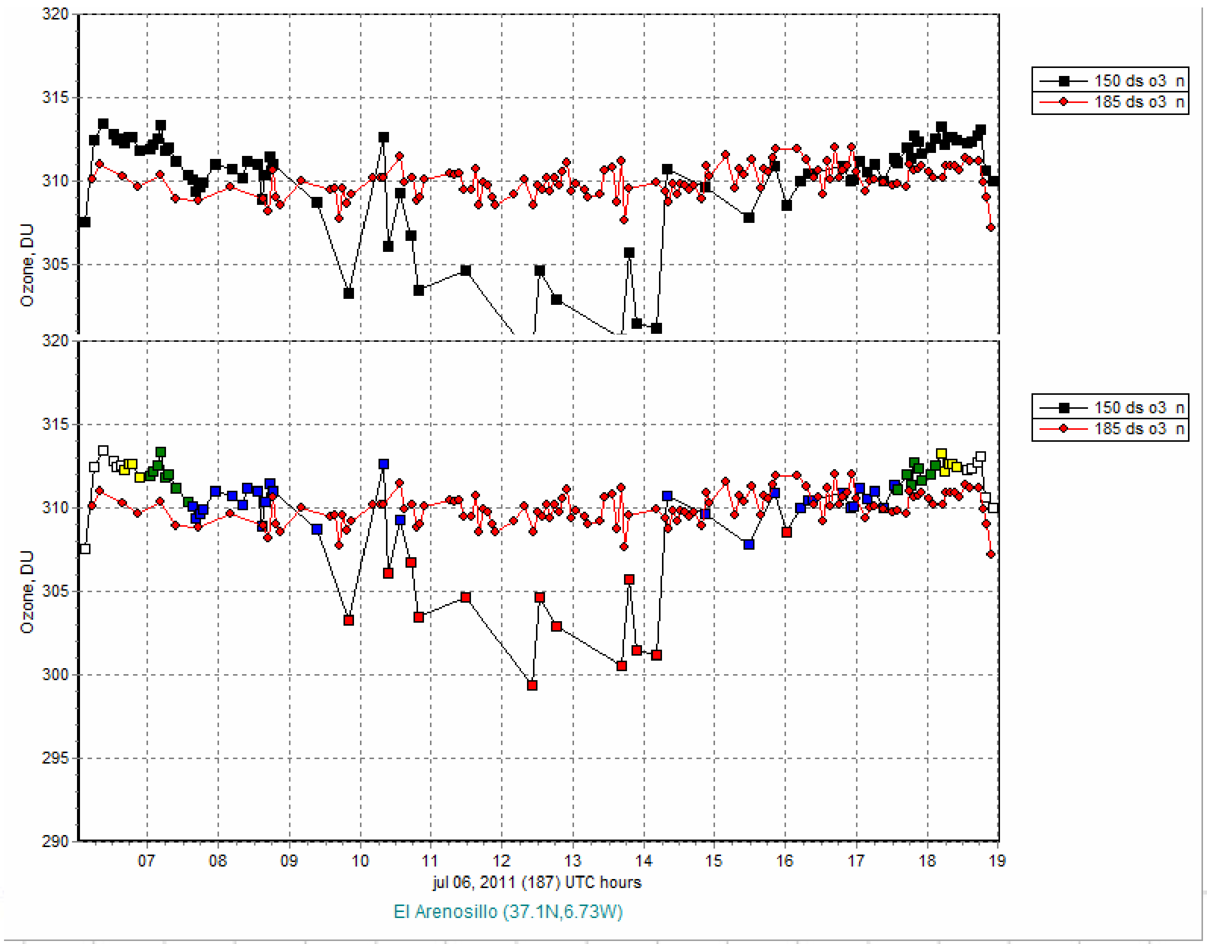
Attenuation filter issues in brewer ozone calculations

1. Introduction
2. Ozone algorithm
3. Ozone Filter Correction
4. Methods for Filter issues detection and correction determination

Brewer Workshop Beijing September 13

No linearity of the attenuation filter is a know issue on the brewer ozone calculation

(see for example Volodya Savastiouk Phd Thesis 2008)



$$O_3 = \frac{\sum_{i=1}^{4} w_i \cdot \left[Log(F_i) - Log(Fo_i) - AMF_{SCA} \cdot \frac{p}{p_0} \cdot \tau_{SCAi} \right]}{AMF_{O3} \cdot \sum_{i=1}^{4} w_i \cdot \tau_{O3i}}$$

weights w_i : –1, +0.5, +2.2, and –1.7

Wavelengths : 310, 313, 317, and 320nm .

Fo : extraterrestrial count rates.

F : measured count rates

P_0 ,p : standard surface air pressure /average station air pressure

τ_{SCAi} : molecular scattering optical depths for each wavelength I at po.

τ_{O3i} : ozone absorption optical depths for each wavelength i.

AMF_{SCA} : direct sun air mass factors for molecular scattering

AMF_{O3} : direct sun air mass factors for ozone absorption respectively.

$$AMF_x = \sec\left\{ \arcsin\left[\frac{R}{R + h_{EFFx}} \cdot \sin(SZA) \right] \right\}$$

R is the Earth's radius (6370km)

h_{EFFx} is the effective layer height. (It is set to h_{EFFSCA}=5km and h_{EFFO3}=

In a ideal brewer the ozone do not depend of the attenuation filter.

1. Attenuation Filters are “neutral”
2. Nominal wavelengths and weights verify :

$$\sum_{i=1}^{4} w_i = 0, \qquad \sum_{i=1}^{4} w_i \lambda_i = 0$$

If the attenuation is linear with wavelength, do not affect the ozone calculation.

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Attenuation Filter : Ozone Algorithm

$$f \equiv Count\ Rates\ , F = \log(f)$$

$$F_i = F_i + Af_{Filter\#} + CT_i * (Temp)$$

$$R6 = \sum_{i=1}^{4} w_i F_i$$

$$Af(\lambda) = Af + \lambda \Delta Af + ..$$

$$R6 = \sum_{i=1}^{4} w_i F + Af \sum_{i}^{4} wi + \Delta Af \sum_{i=1}^{4} w_i \lambda_i$$

$$\sum_{i=1}^{4} w_i = 0, \qquad \sum_{i=1}^{4} w_i \lambda_i = 0$$

In a real instrument

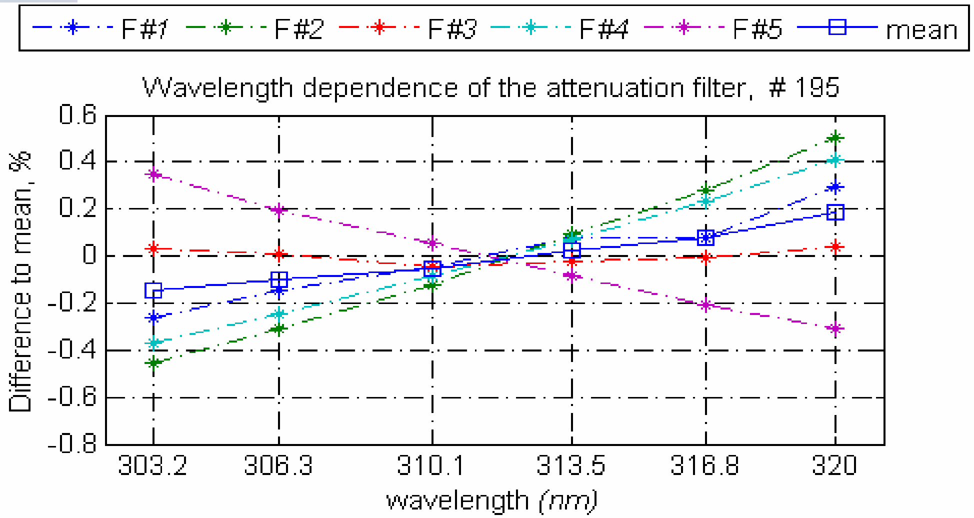
a) the filters can not be neutral

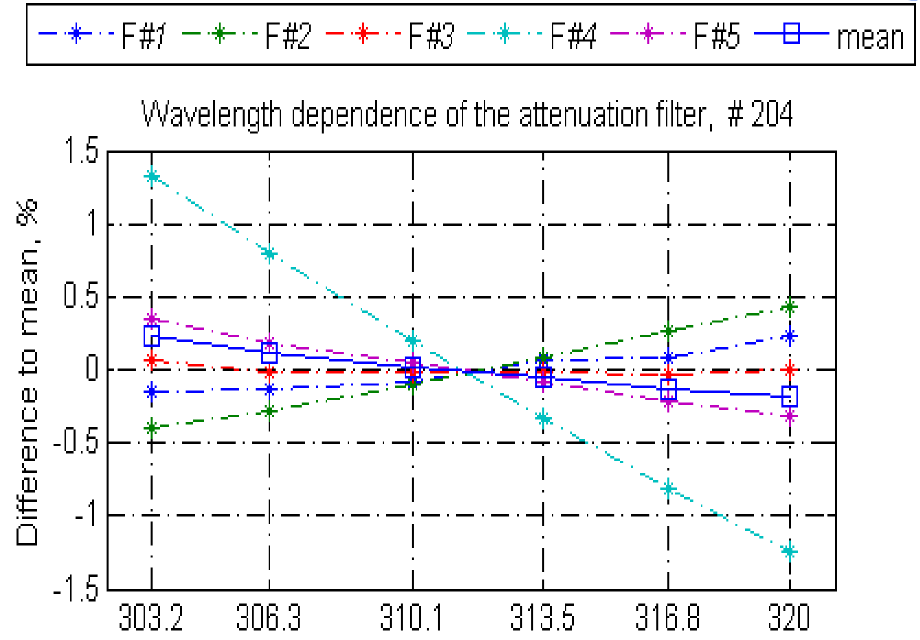
b) Even if there are linear with wavelengths

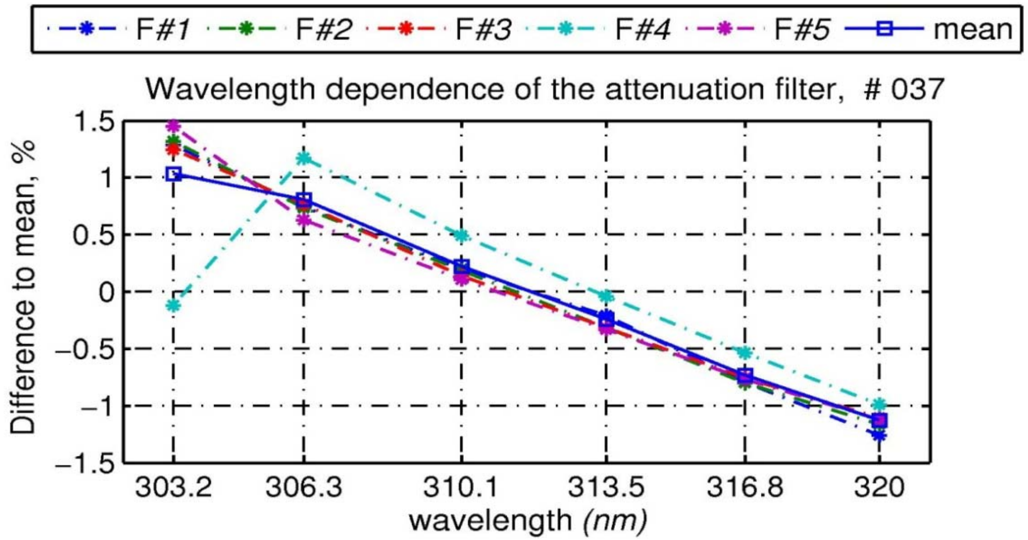
$$Af(\lambda) = Af + \lambda \Delta Af \qquad \sum_{i=1}^{4} w_i \lambda_i \approx 0$$

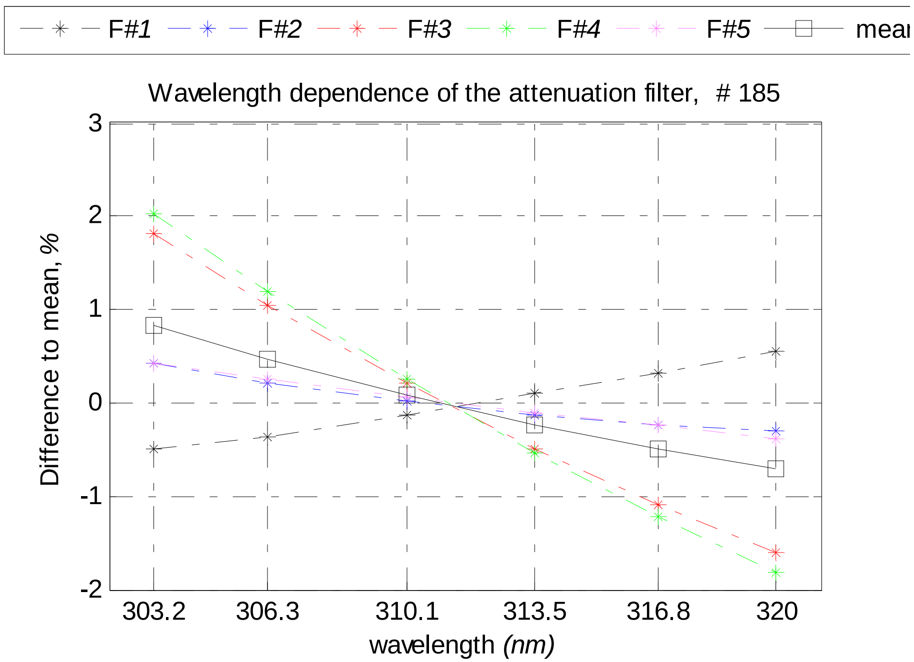
$$R6(f\#) = R6 + \Delta Af \sum_{i=1}^{4} w_i \lambda_i$$

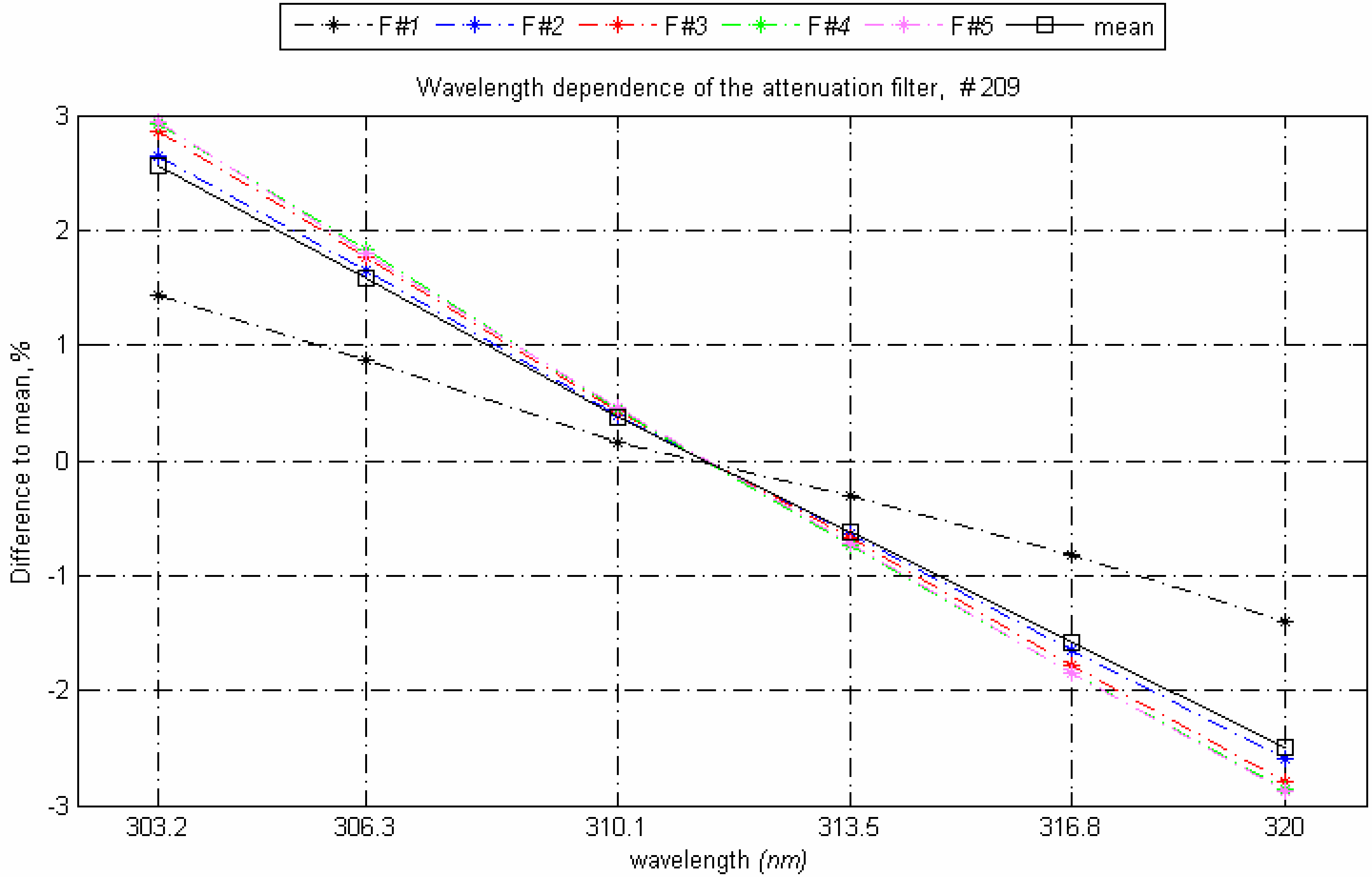
If the slope is to big you see the effect in the ozone.


F#1
F#2
F#3
F#4
F#5
mean
Wavelength dependence of the attenuation filter, # 195
Difference to mean, %
wavelength (nm)
303.2
306.3
310.1
313.5
316.8
320


F#1
F#2
F#3
F#4
F#5
mean
Wavelength dependence of the attenuation filter, # 204
Difference to mean, %
303.2
306.3
310.1
313.5
316.8
320


F#1
F#2
F#3
F#4
F#5
mean
Wavelength dependence of the attenuation filter, # 037
Difference to mean, %
wavelength (nm)
303.2
306.3
310.1
313.5
316.8
320


F#1
F#2
F#3
F#4
F#5
mea
Wavelength dependence of the attenuation filter, # 185
Difference to mean, %
wavelength (nm)
303.2
306.3
310.1
313.5
316.8
320


F#1
F#2
F#3
F#4
F#5
mean
Wavelength dependence of the attenuation filter, #209
Difference to mean, %
3
2
1
0
-1
-2
-3
303.2
306.3
310.1
313.5
316.8
320
wavelength (nm)

The effect can be accounted using a ETC correction for the affected filter.

If you know the attenuation of every wavelengths

$$ETC\_C(j) = \sum_{i=1}^{4} w_i Af(\lambda_i, j)$$

The correction in can be implemented as the ussual Standard Lamp correction.

Determination of the ETC correction

a) Internal test using Direct Sun
b) Filter wavelength dependence
   a) FI.RTN, FWTEST
   b) AT.RTN
c) Calibration
d) Langley

Internal Test

This procedure check on the data record if one particular brewer is affected by this issue and estimate the correction.

We look in to the ozone differences in simultaneous measurement performed with different filter

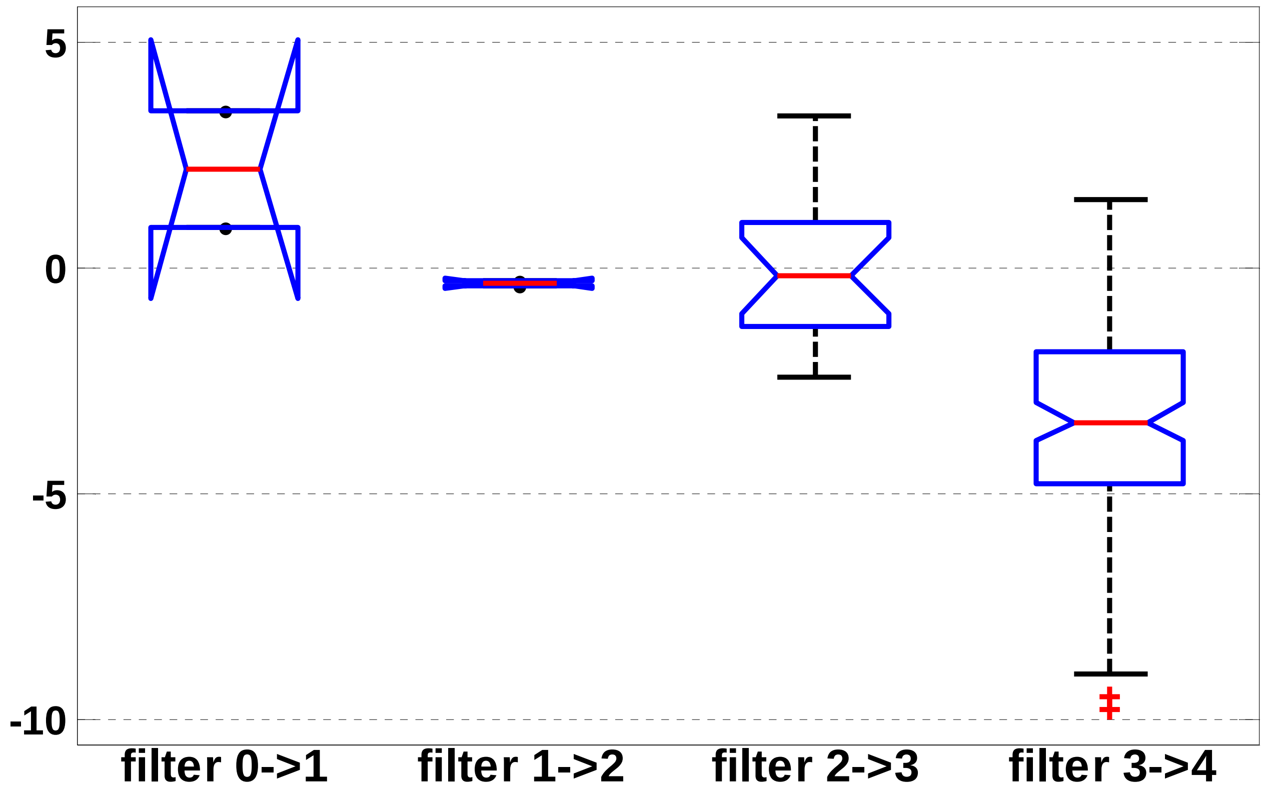
Requires a long record (one year) of ozone measurement without changes on the instrument calibration

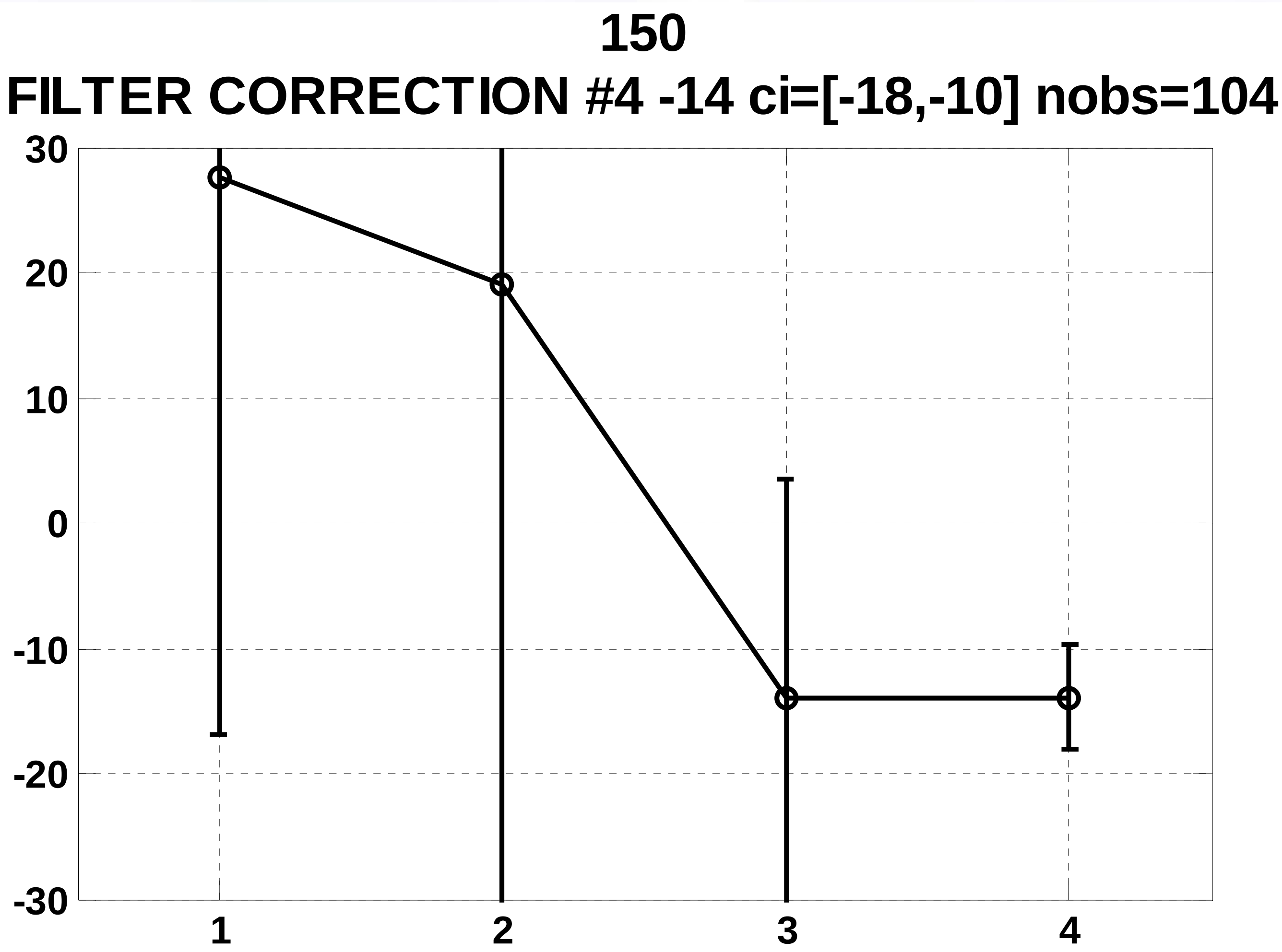
With for example Martin Stanek's O3Brewer produce a report with include : Date , time,filter, airmass, ozone, MS9

Select simultaneous measurements (10 min, airmass <0.05), performed with different filter.

Look for significant differences on the statistics from f#3 to f#4, (you have only significance for high air mass)

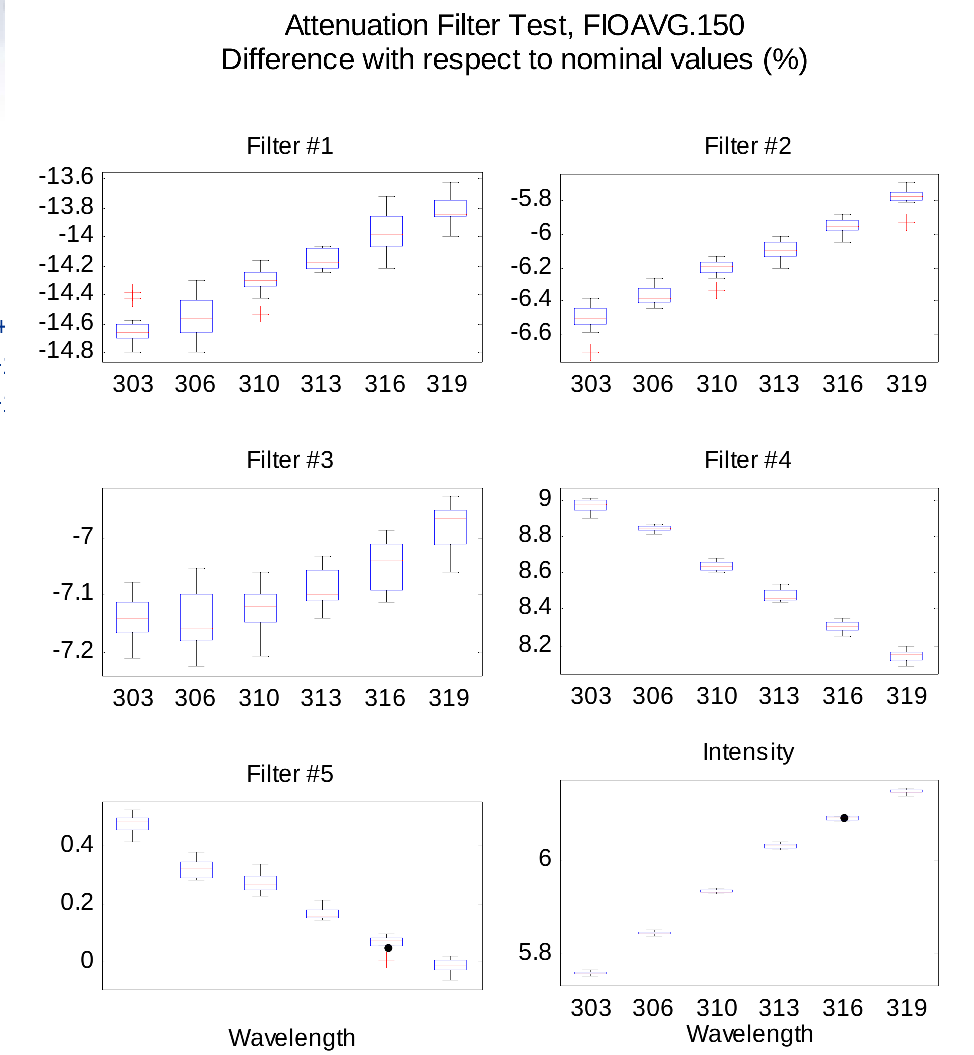
150
Ozone (DU) difference by filter change

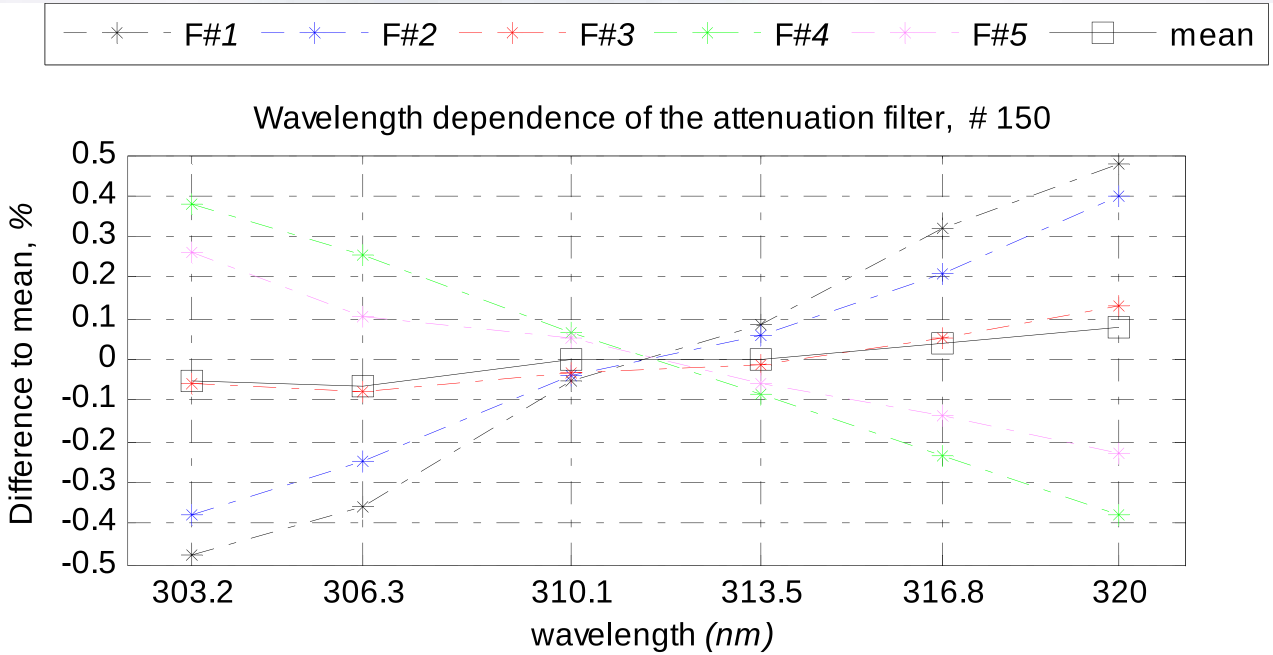



150
FILTER CORRECTION #4 -14 ci=[-18,-10] nobs=104
30
20
10
0
-10
-20
-30
1
2
3
4

Filter Characterization : FI.RTN

```
% IOS description of the fi test output in fioavg.\#\#\# file
 % (created by V. Savastiouk)
 %
 % date Te AF  CY  N  Slit0 std Slit1 std Slit2 std Slit3 std Slit4 std Slit5 std
 % 28003 9  1   1  3  49815 +37 59776 +0  60031 +0  60318 +0  59622 +0  58465
 %          2   3  3   4520 +17  4514 +13  4504 +5   4492 +7   4482 +5   4474 +16
 %          3   8  3   9386 +16  9338 +24  9296 +3   9245 +7   9211 +6   9186 +22
 %          4  30  3  16396 +24 16262 +17 16105 +17 15976 +7  15863 +11 15752 +
 %          5 100  3  24598 +55 24357 +9  24155 +18 24003 +9  23873 +9  23736 +.
 %          6 250  3  25996 +54 25764 +0  25553 +13 25411 +0  25251 +0  25103 +.
 %
 % Te - temperature,
 % AF - FW2 position,
 % CY-number of cycles for that AF
 % N - number of repetition (fi does several loops one inside the other and N
 % is the outer most loop).
 % Slit0-6 are the values for the attenuations, except for AF=1
```



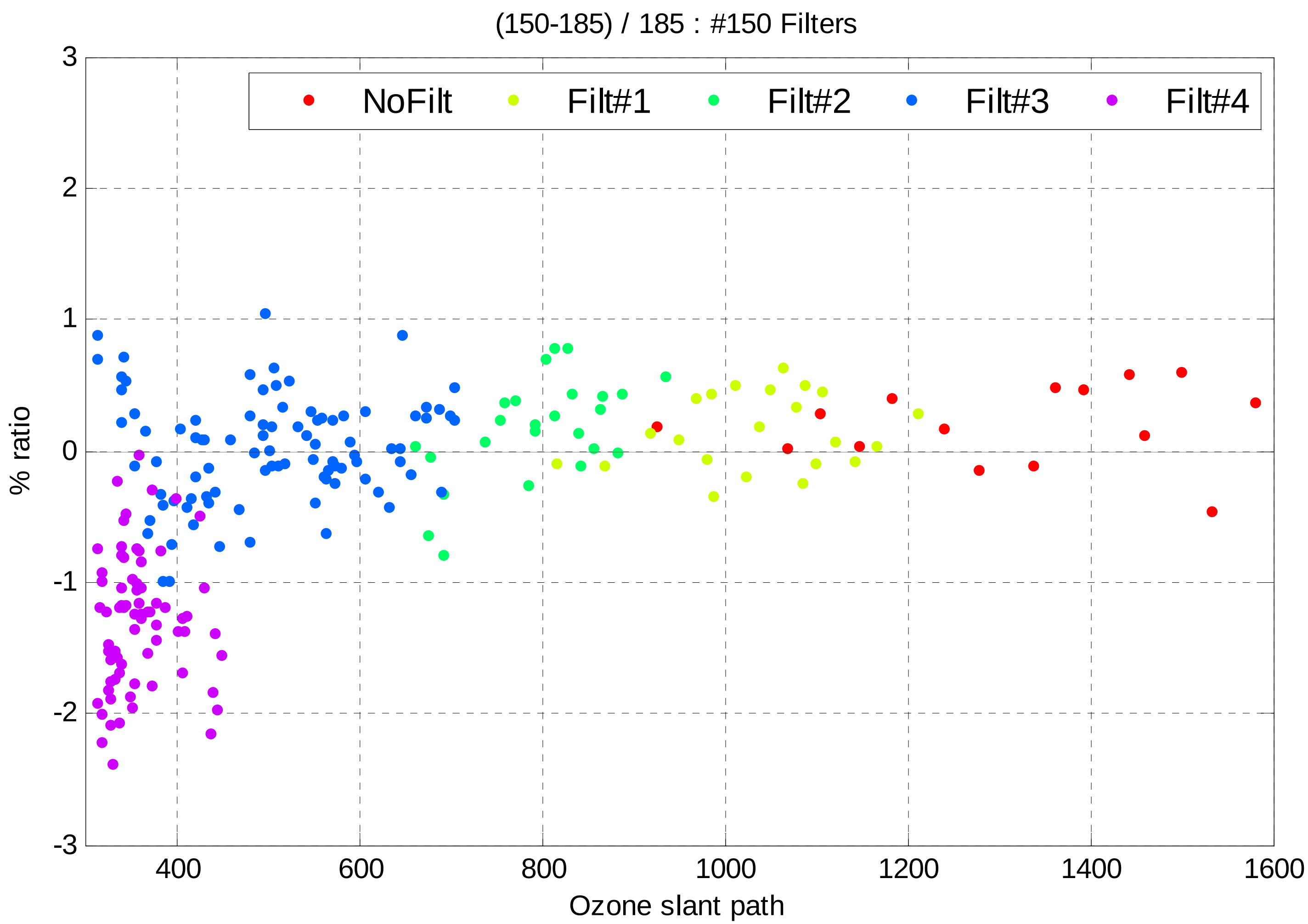


	filter #1	filter #2	filter #3	filter #4	filter #5
slit #0	4267	9349	13929	21794	25120
slit #1	4272	9361	13926	21767	25081
slit #2	4285	9381	13932	21726	25068
slit #3	4291	9390	13935	21693	25040
slit #4	4301	9404	13944	21661	25020
slit #5	4308	9422	13955	21630	24998
mean	4287	9384	13936	21711	25054

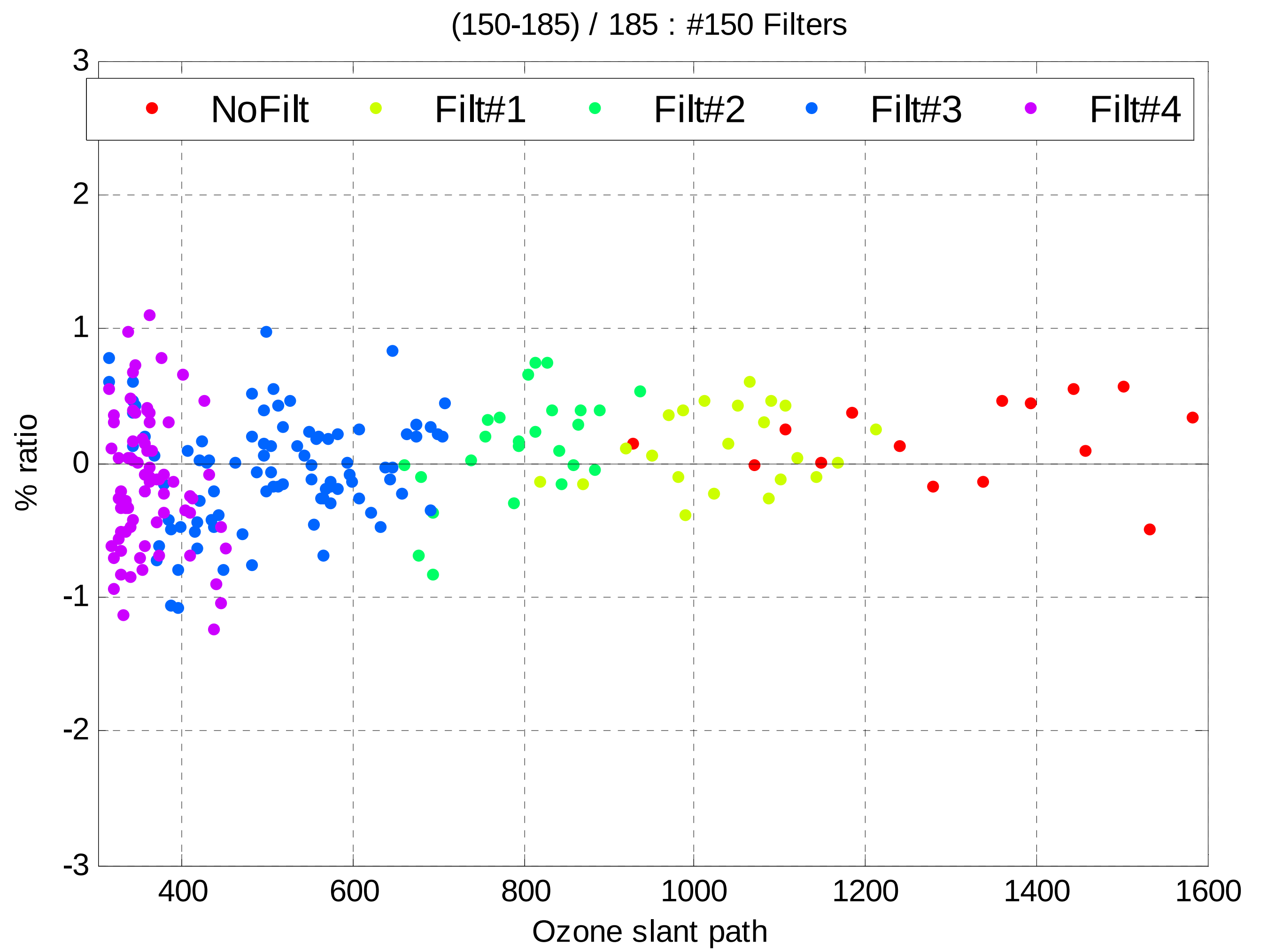
$$ETC\_C(j)=\sum_{i=1}^{4} w_i Af(\lambda_i, j)$$

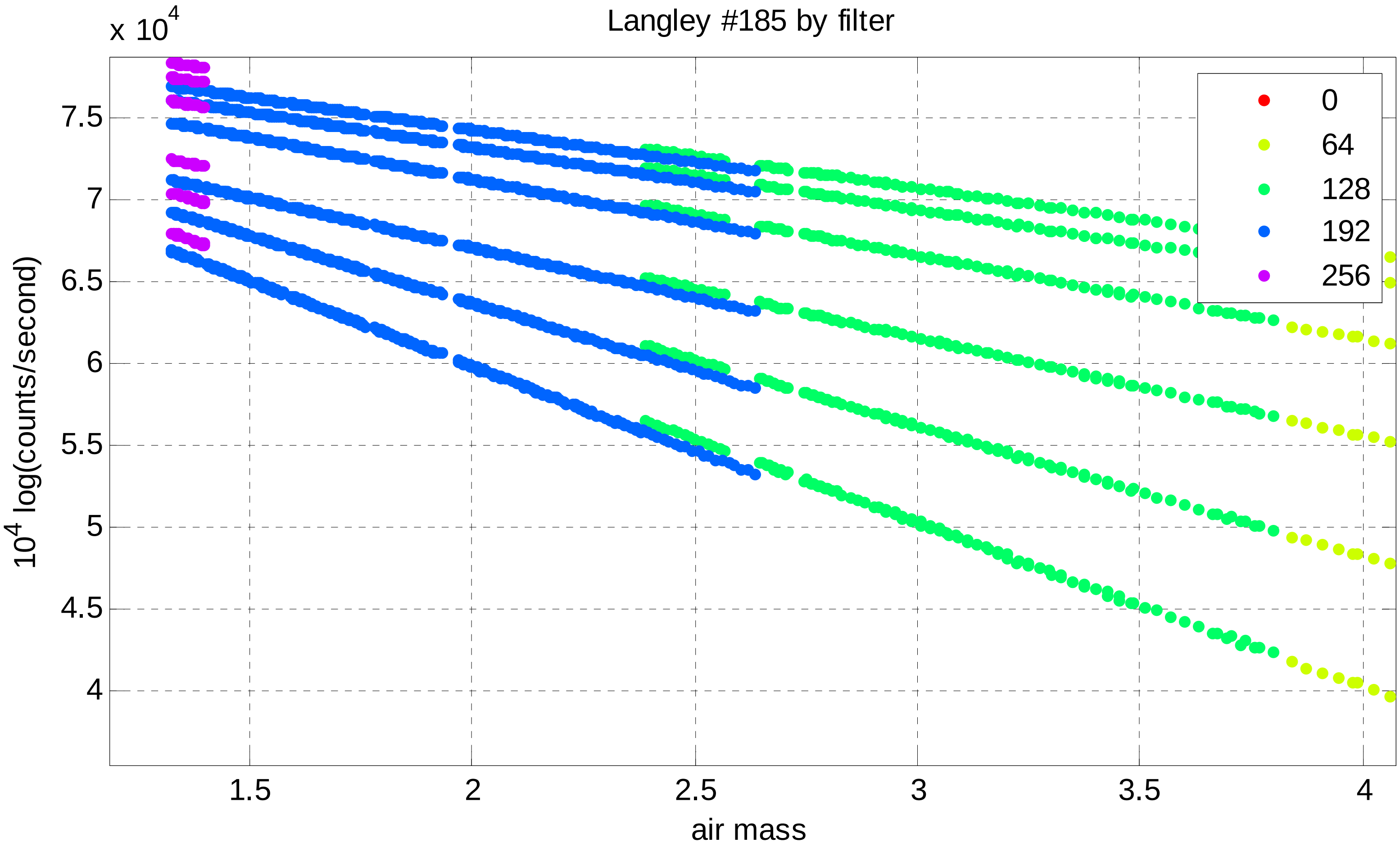
	filter #1	filter #2	filter #3	filter #4	filter #5
ETC Filt. Corr. (median)	-1	-15	-11	4	-1
ETC Filt. Corr. (mean)	-1.17	-12.03	-7.9	8.7	-3.86
ETC Filt. Corr. (CI)	-10.78	-18.79	-15.74	3.3	-13.08
ETC Filt. Corr.(CI)	7.27	-3.60	-0.46	11.7	3.67

Comparison with other instrument

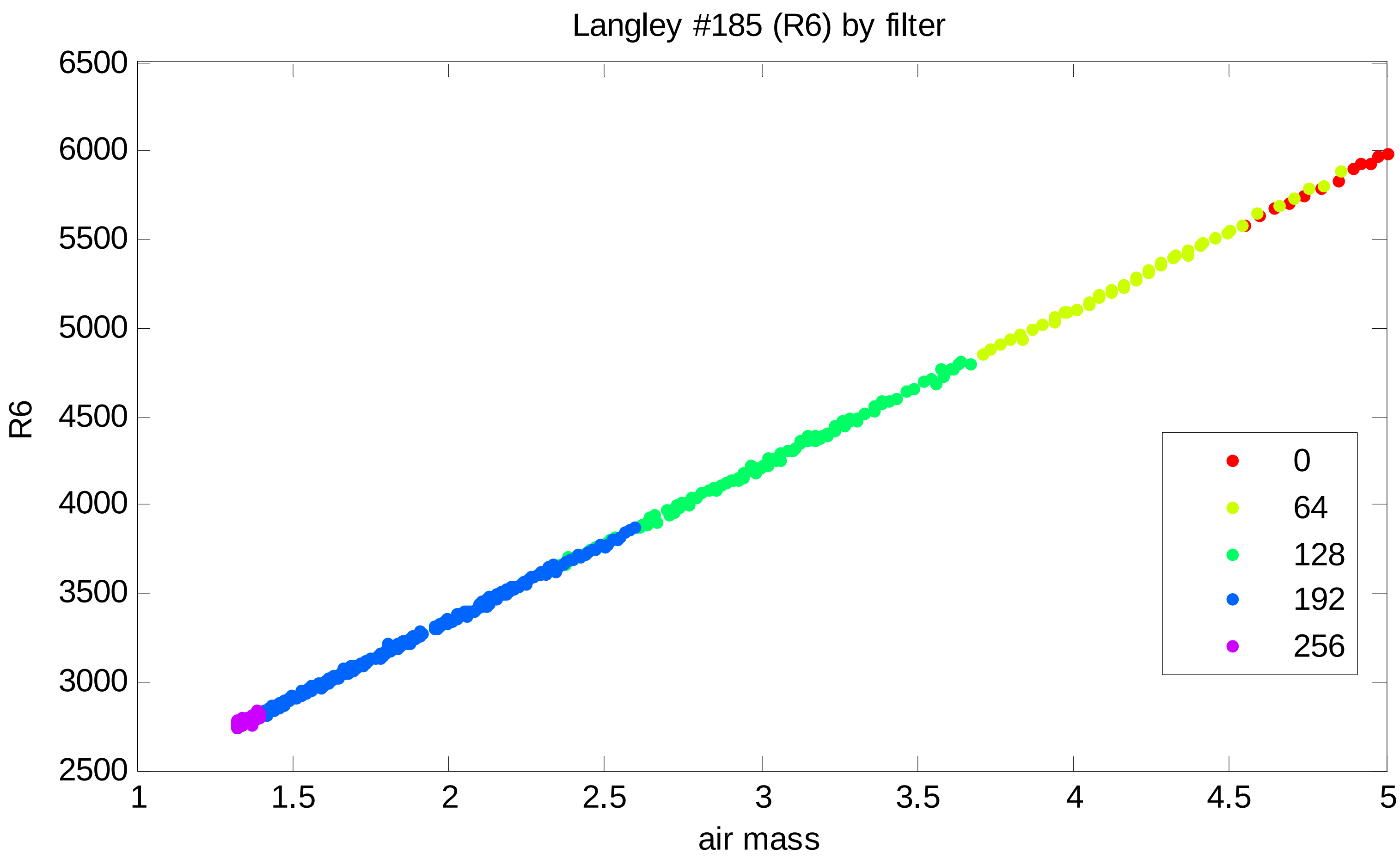


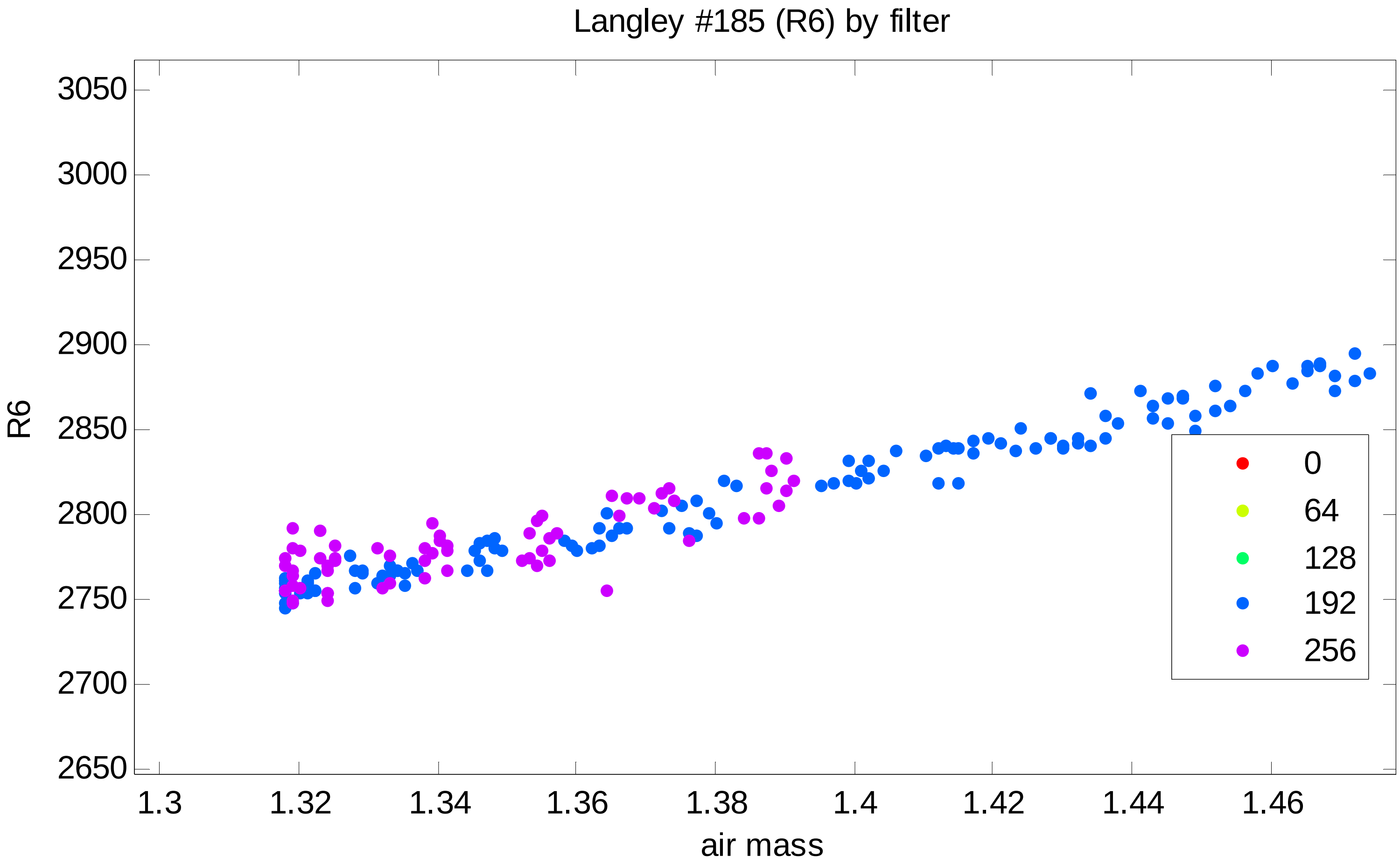
Comparison with other instrument



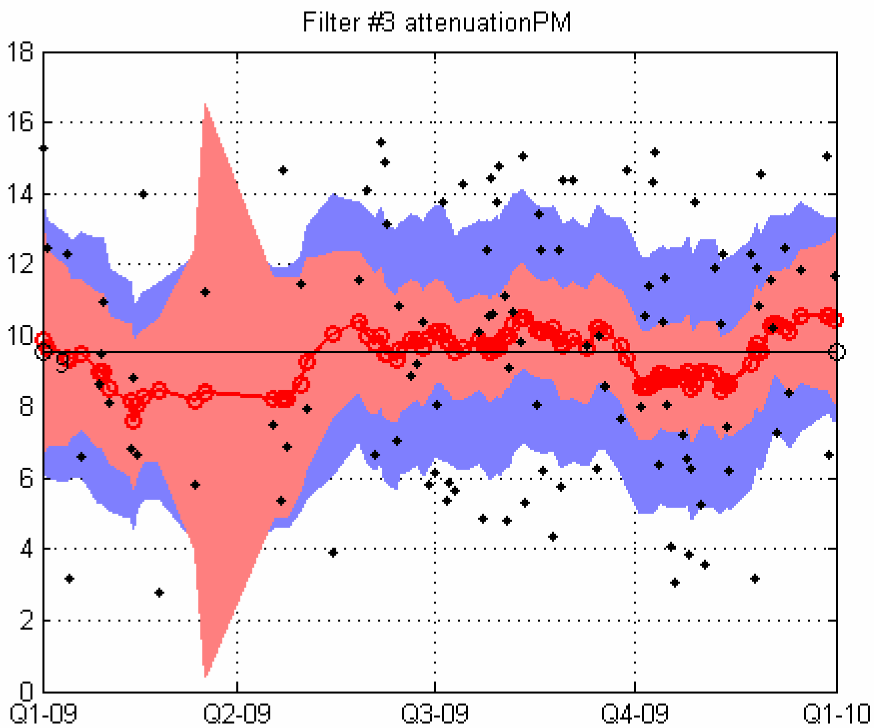


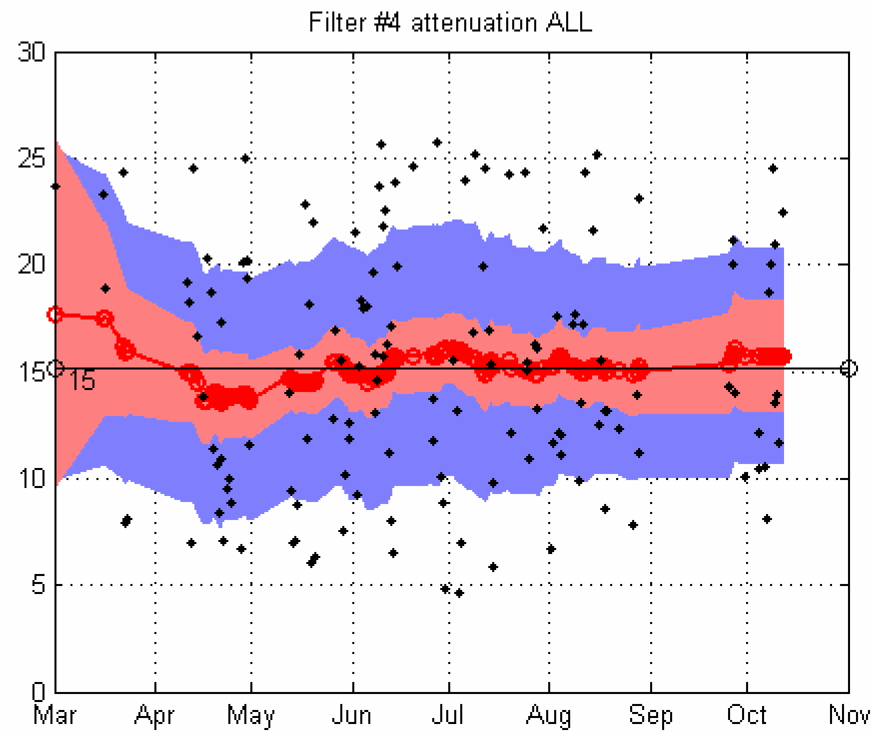
Langley #185 by filter
x 10^4
10^4 log(counts/second)
7.5
7
6.5
6
5.5
5
4.5
4
1.5
2
2.5
3
3.5
4
air mass
0
64
128
192
256


Langley #185 (R6) by filter
6500
6000
5500
5000
4500
4000
3500
3000
2500
R6
1
1.5
2
2.5
3
3.5
4
4.5
5
air mass
0
64
128
192
256

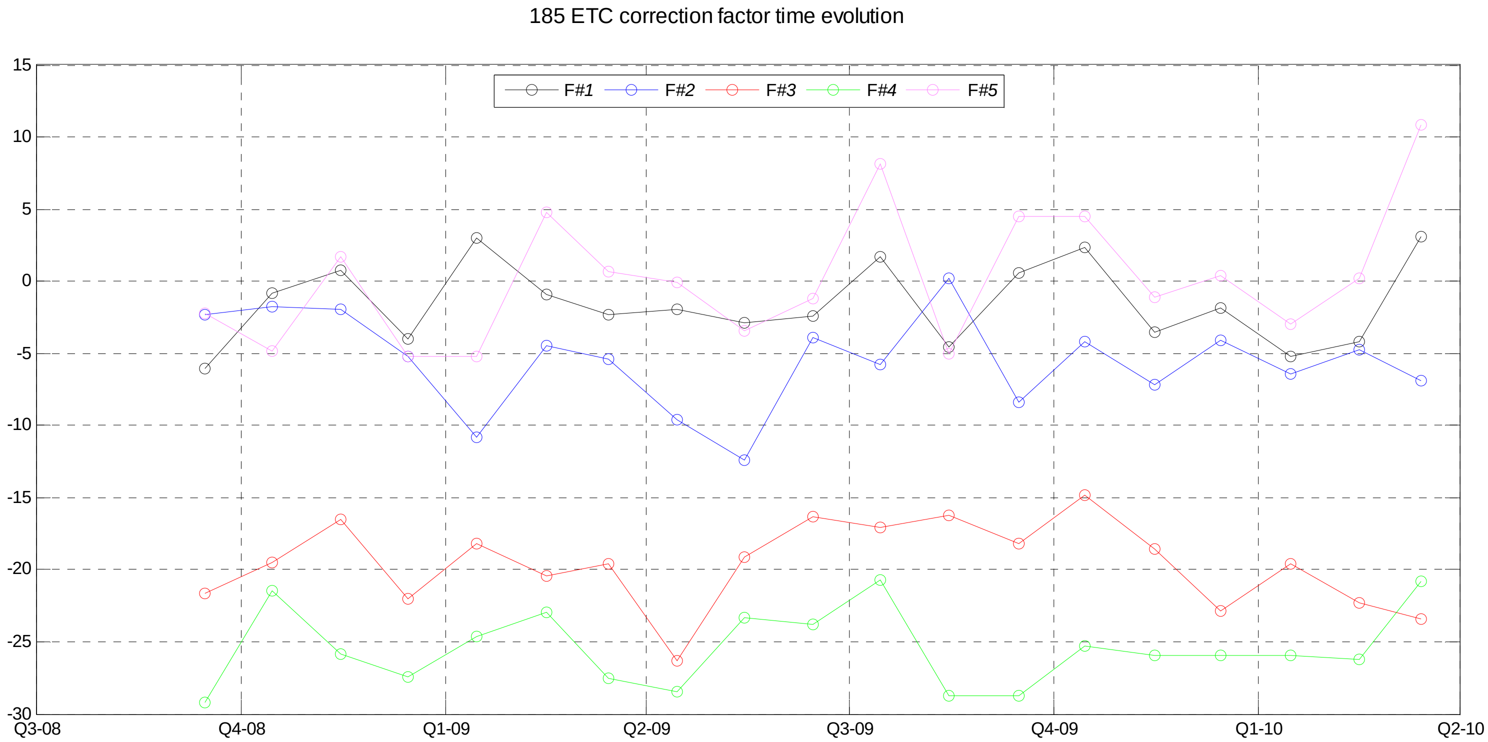

Langley #185 (R6) by filter
R6
3050
3000
2950
2900
2850
2800
2750
2700
2650
1.3
1.32
1.34
1.36
1.38
1.4
1.42
1.44
1.46
air mass
0
64
128
192
256

- Langley determination of the ETC correction





#185 FI results



	F1	F2	F3	F4	F5
Median	-2.	-7.	-22.	-25.	-0.
Mean	-2.	-5.	-20	-26	-0.
ci	-3.	-7.	-21	-27	-2.
ci	-0.	-4.	-18	-24	2.

Attenuation Filter Check

Method		Contras	
FI		Requires a large number of measuremetns	
AT		Need evaluation	
Reference Comparison		Error in reference	
Internal comparison		Enough data during intercomparison ?	
ETC calculation		Filter & airmass are correlated, sometimes regression fail	

TODO LIST

Explain de difference langley- FI

Evaluate the performance of AT routine

Evaluate for every instrument $\sum_{i=1}^{4} w_i \lambda_i \approx 0$

Dead Time – Filter dependence

Recommendations:

When produce the summary of your data , don`t forget to store the filter.

Introduce the FI routine in your schedule , at the end of the day.

$$Ri = stored\ readings\ for\ slit\ i$$

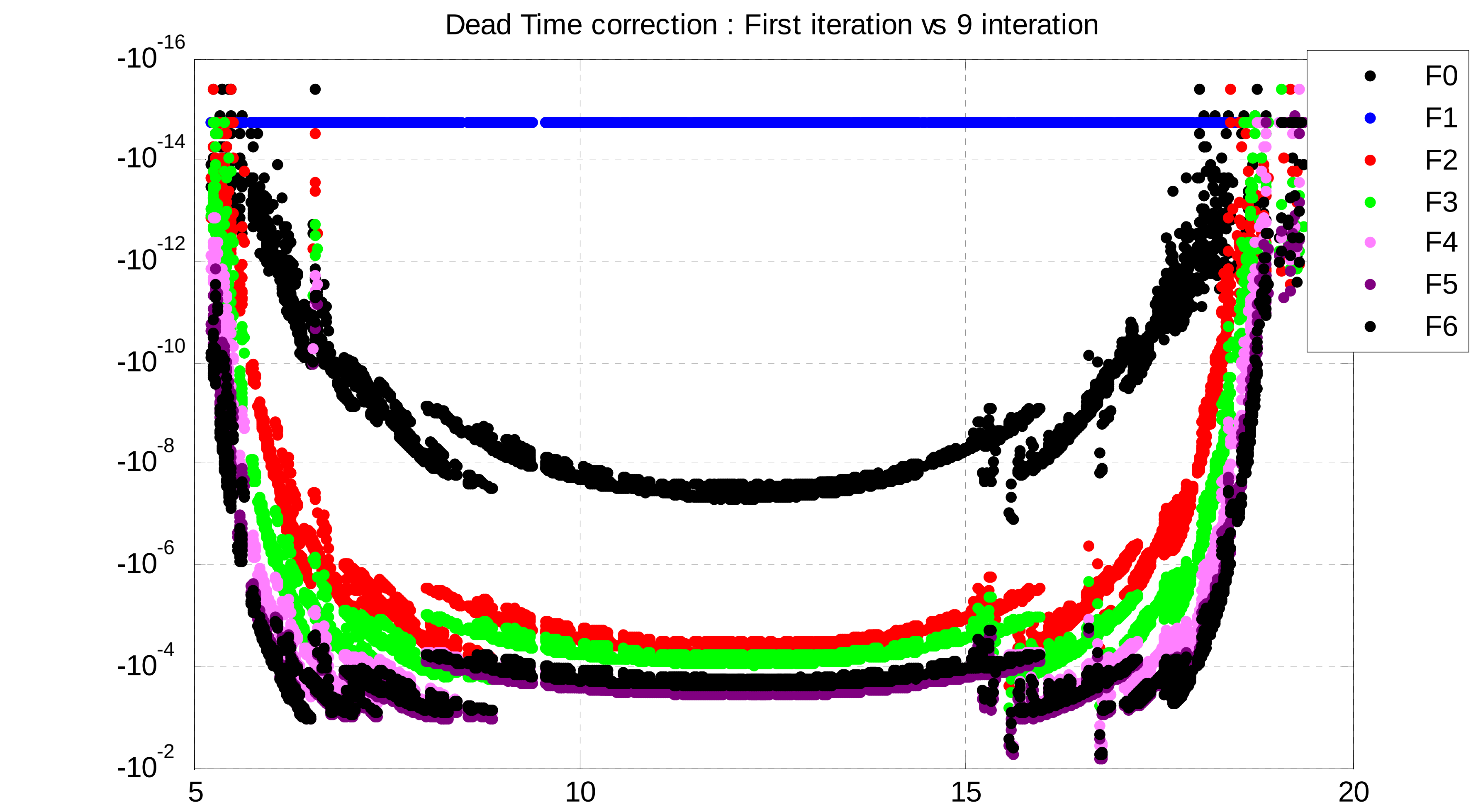
$$R_{oi} = \frac{2 * R_{ri} - R_{dark}}{Cy * IT} counts / seg$$

$$R_{di} = R_{oi} \exp(R_{di} * DT)$$

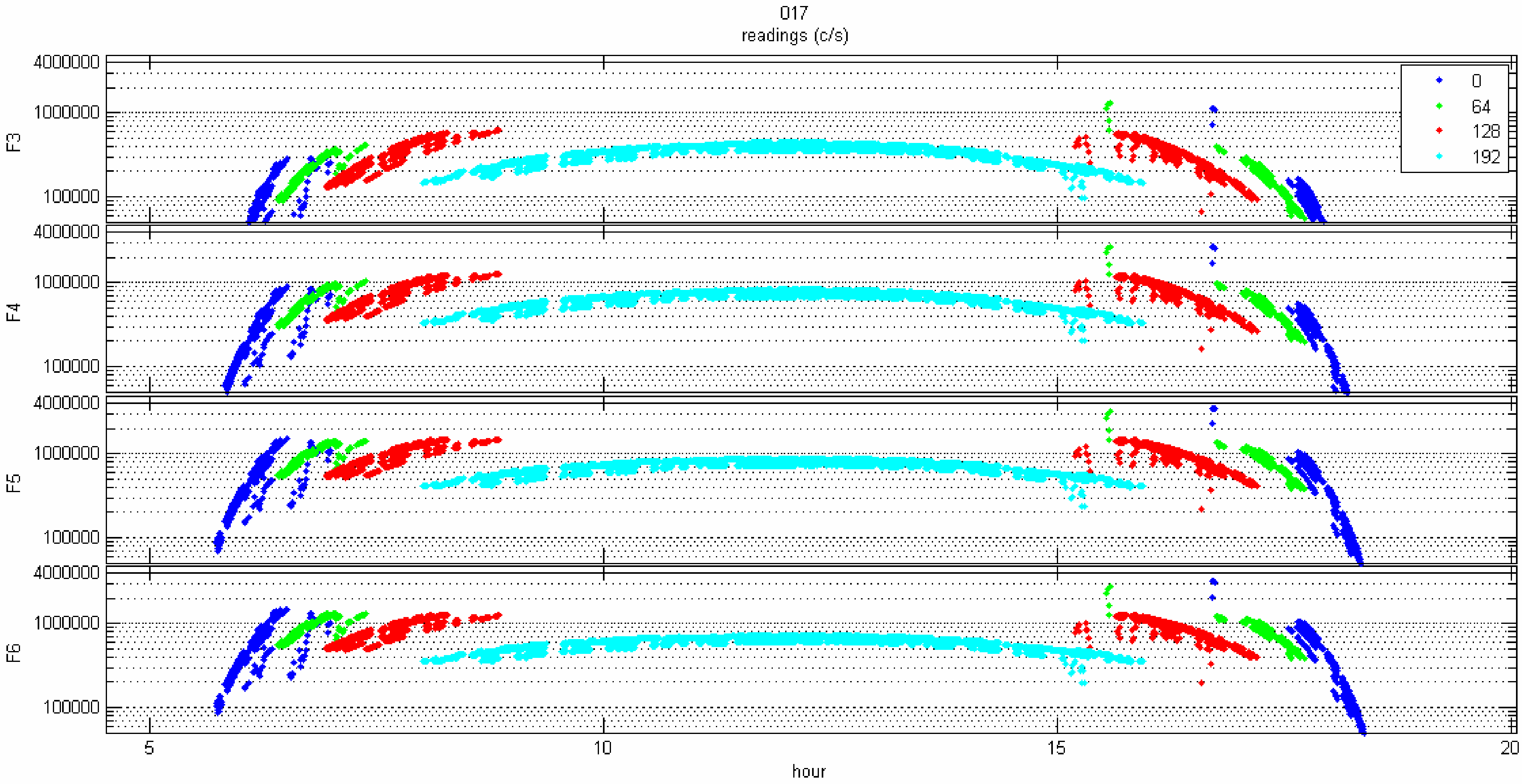
$$F_s = \log(R_{di}) * 10 \wedge 4 \approx 10 \wedge 4 * \log(Ro) + Ro * DT$$

$$F = F + T_{ci} * temp + AF_f (filter)$$

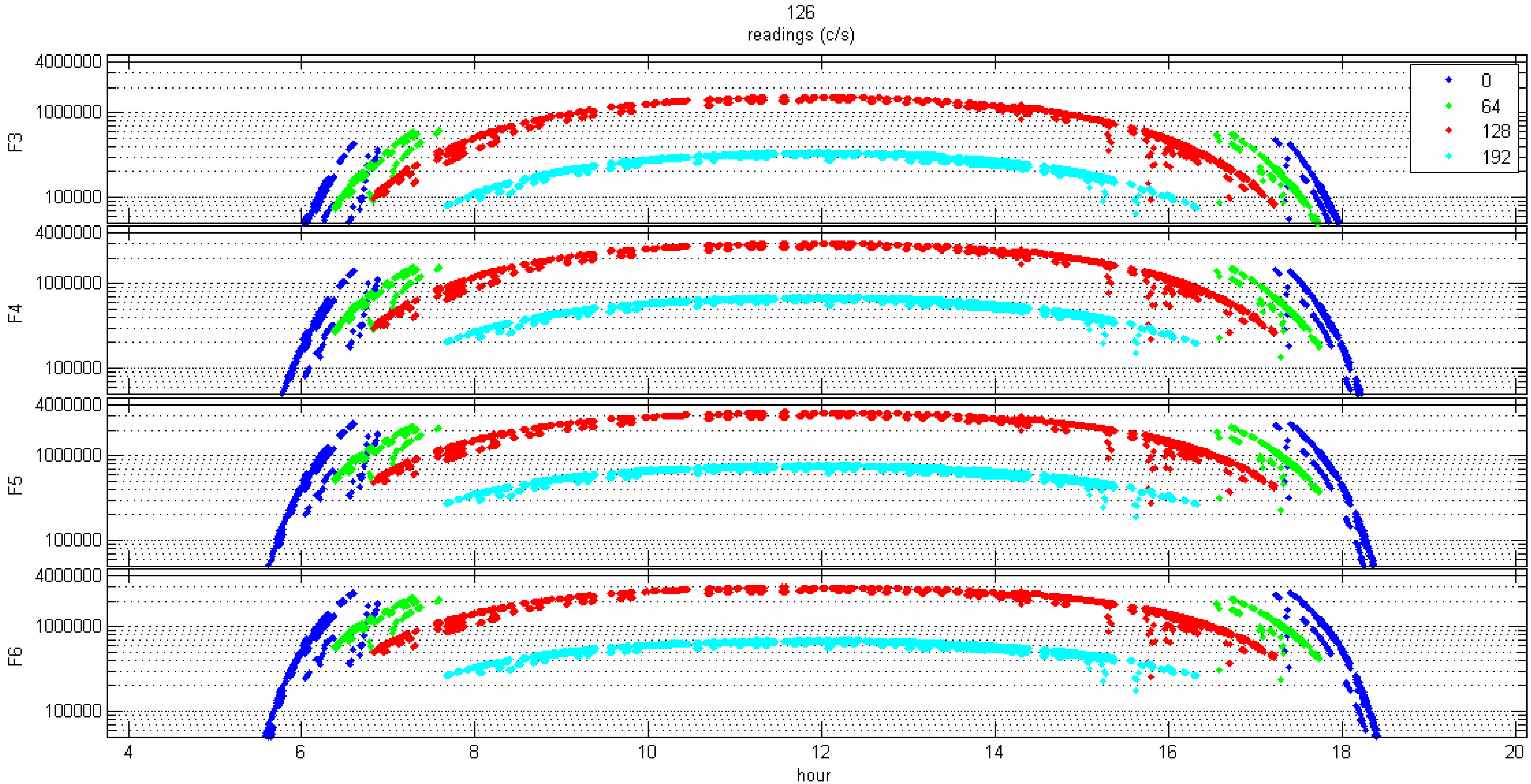
$$F = F_d + T_{ci} * temp + AF(filter) + R_i * m_a$$



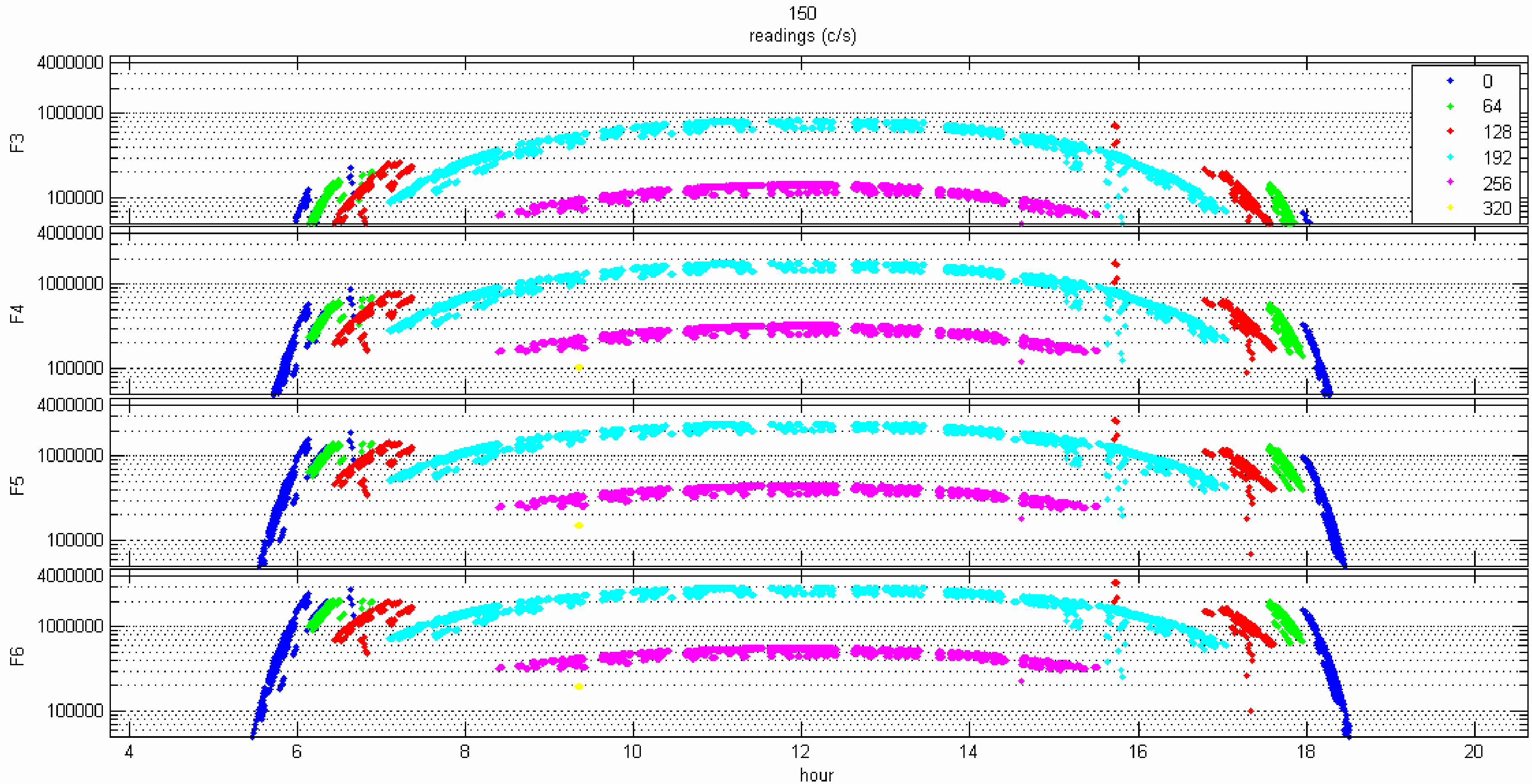
Dead Time correction : First iteration vs 9 interation
-10^-16
-10^-14
-10^-12
-10^-10
-10^-8
-10^-6
-10^-4
-10^-2
5
10
15
20
F0
F1
F2
F3
F4
F5
F6

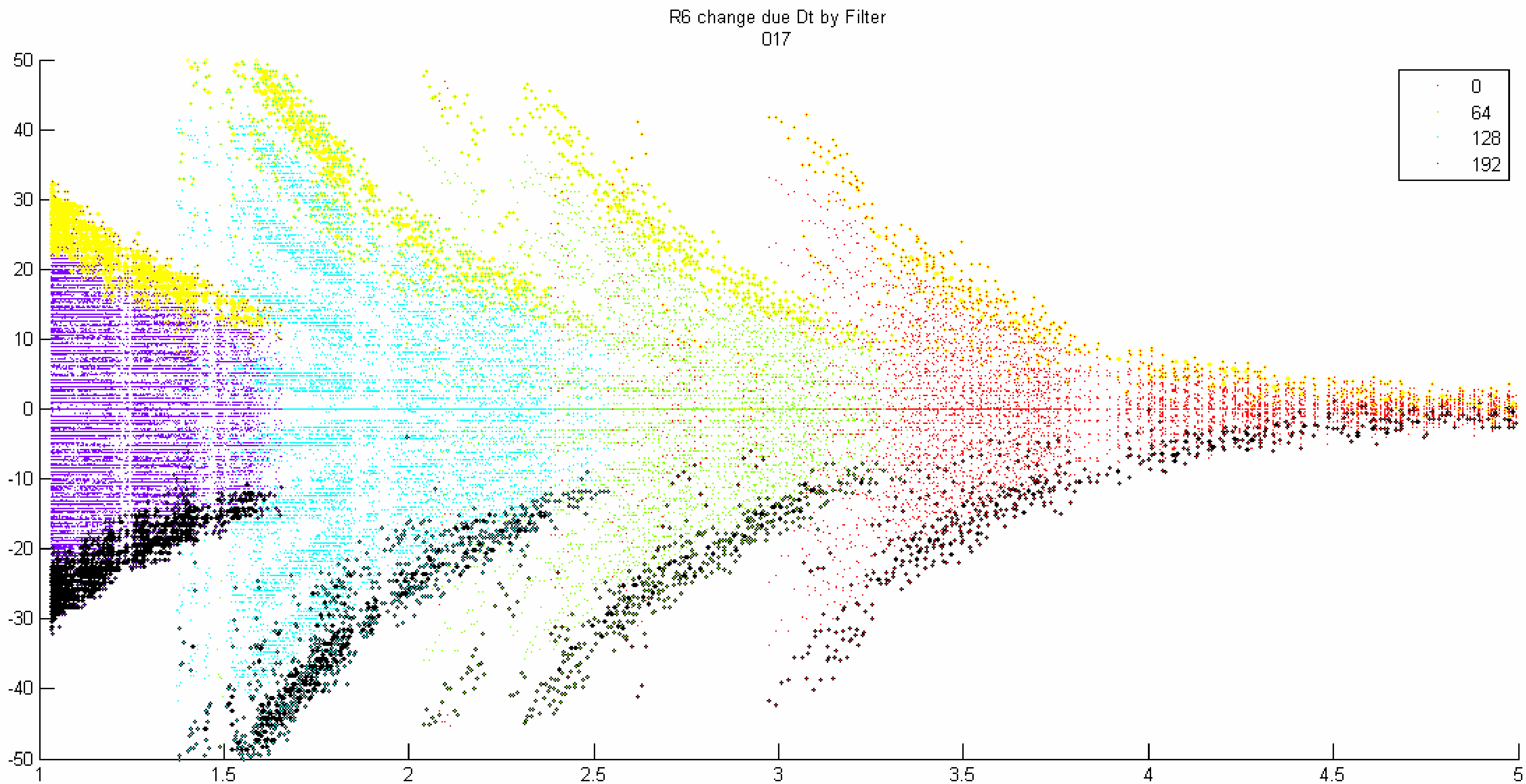


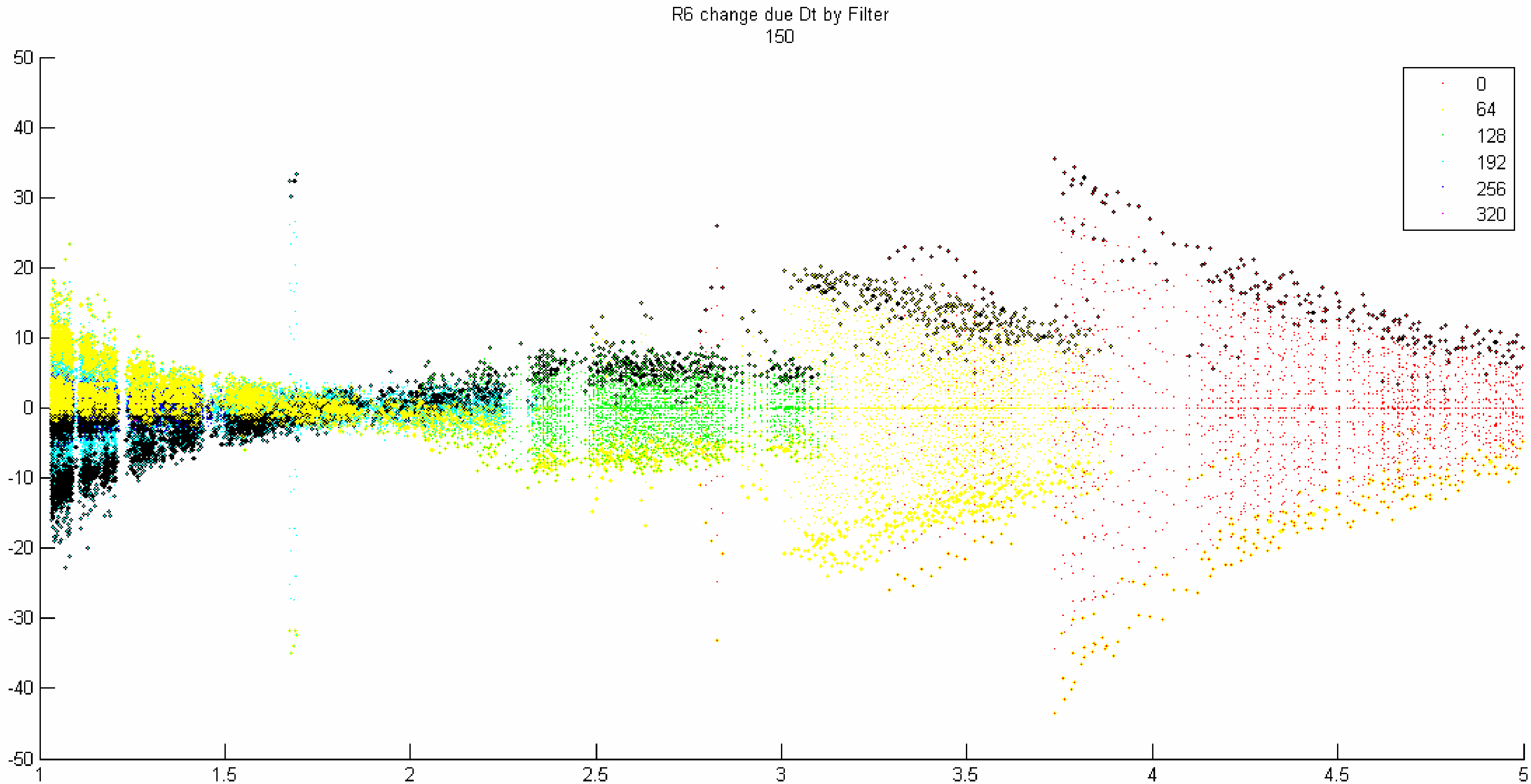
017
readings (c/s)
4000000
1000000
100000
F3
F4
F5
F6
0
64
128
192
5
10
15
20
hour



126
readings (c/s)
4000000
1000000
100000
F3
F4
F5
F6
0
64
128
192
4
6
8
10
12
14
16
18
20
hour


150
readings (c/s)
4000000
1000000
100000
F3
F4
F5
F6
0
64
128
192
256
320
4
6
8
10
12
14
16
18
20
hour


R6 change due Dt by Filter
017
0
64
128
192
50
40
30
20
10
0
-10
-20
-30
-40
-50
1
1.5
2
2.5
3
3.5
4
4.5
5


R6 change due Dt by Filter
150
50
40
30
20
10
0
-10
-20
-30
-40
-50
1
1.5
2
2.5
3
3.5
4
4.5
5
0
64
128
192
256
320